Sideband power measurement

by G. L. BENBOW, G3HB*

IN ORDER TO UNDERSTAND the problem of ssb power measurement, it is useful to examine some of the ideas about amplitude modulation (a.m.). Amplitude modulation is the variation of the amplitude of the rf carrier wave produced by the transmitter. This is achieved by the audio frequency (ie speech) modulating waveform being amplified in the modulator and impressed on the pa power supply via the modulation transformer. The resulting waveform is the familiar modulation envelope shown in Fig 1. Amplitude modulation produces frequencies known as sidebands on either side of the carrier wave, as shown in Fig 2, another familiar diagram. These sidebands are related to the carrier (rc) and modulating (rm) frequencies. The power level of an a.m. transmitter was usually determined by measuring the input power to the output stage, ie the product of the voltage applied and the current drawn by the device(s), be they thermionic or semiconductor, in the power amplifier. The new licence schedule has changed this to 20dBW (100W) carrier power supplied to the antenna, but this does not affect the measurement technique for ssb.

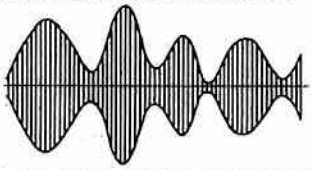

Fig 1. Waveform of an amplitude modulated transmission (modulation envelope)

Fig 1 shows that an increase in the amplitude of the modulated waveform is followed immediately by a decrease; thus an increase in the current drawn by the pa is followed by a decrease. The current drawn by an amplitude modulated pa as measured by the pa current meter is therefore constant; any variation in this current indicates non-linearity or maladjustment of the pa. The input power is simply the product of a constant voltage and a constant current, and is very easy to measure.

Referring again to Fig 2, both sidebands contain the same intelligence and as the carrier wave contains no intelligence, no intelligence is lost if the carrier wave is suppressed and one or other of the sidebands is eliminated. By this process the familiar single sideband (ssb) mode of transmission is obtained.

Now, a more complex situation arises, the current drawn by the pa is no longer constant, it varies at a syllabic rate. A typical pa input current waveform of an ssb transmitter is shown in Fig 3. The output waveform will be the same; Fig 3 shows that only one thing can be defined about this waveform, ie, its maximum or "peak" value, which does not occur often. Any other value, such as the rms or the average, which could be applied to a sinusoidal waveform is meaningless, as the waveform is not regular, but depends on the voice pattern (male or female voice for instance) and the syllables being spoken.

The syllabic variations in the current which are represented by the waveform of Fig 3 are too rapid for it to be measured in the usual way. The pointer-type meter is much too sluggish in operation and would only indicate 50–70 per cent of the peak value. Consequently, the input power of an ssb transmitter cannot be measured in the same way as that of one which is amplitude modulated.

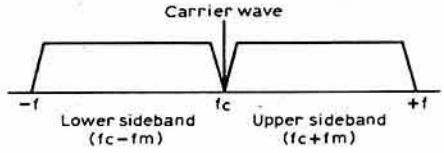

Fig 2. Carrier wave and sidebands of an a.m. transmission (f_c is the carrier frequency, f_m is the modulation frequency)

An alternative way of determining the power level of an ssb transmitter is to measure its output power and, in fact, this is the method prescribed in the UK amateur licence. The power defined in the licence is the peak envelope power (p.e.p.). A certain amount of confusion arises now, because this is not peak power as defined in an electrical engineering text book, but it is the real (rms) power at the instant of the peak of the modulation envelope. The maximum value of the p.e.p. permitted by the UK amateur licence is 400W (26dBW), which is related to the former 150W input figure for a.m. as follows. If the efficiency of the output stage is assumed to be 66·66 per cent, the output power is 100W. When the transmitter is modulated to a depth of 100 per cent, the peak amplitude of the modulation envelope is twice that of the unmodulated carrier wave. The power output in the unmodulated case is V^2/R, where V is the unmodulated carrier amplitude (in volts) and R is the value (in ohms) of the dummy load on the transmitter output. As the amplitude of the carrier wave is doubled when the modulation level is 100 per cent, the power becomes $\frac{(2V)^2}{R}$ or 4. $\frac{V^2}{R}$. Thus the power at the peak of the modulation envelope is multiplied by four, and hence the permitted power level is 4 × 100W, or 400W p.e.p.

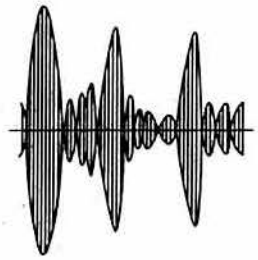

Fig 3. Waveform of an ssb transmission

The usual way of measuring p.e.p. is shown in Fig 4. The transmitter is modulated by a two-tone generator containing two af oscillators producing non-harmonically related sinusoidal tones of equal amplitude which are combined. The output of the transmitter is dissipated in a dummy load and observed on an oscilloscope. The output power of the transmitter may be found by measuring the rf voltage across the dummy load on the oscilloscope (or by an electronic voltmeter) and calculating it from $W = V^2/R$. Alternatively it may be calculated from $W = I^2R$, where I is the rf current in the load measured by an rf ammeter (2–3A max) if available.

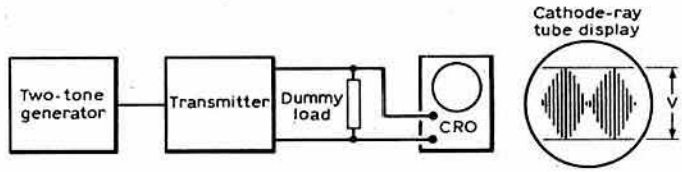

Fig 4. Measurement of peak envelope power

The transmitter is adjusted to produce an output of 200W, measured as above. This power will give rise to a certain deflection on the oscilloscope, and the limits of this deflection can be marked on the tube face or graticule by two thin lines drawn with a chinagraph pencil. It can be shown that the power level of 200W to which the transmitter has been adjusted (with two-tone input) is equivalent to a p.e.p. of twice that value, ie 400W p.e.p.. When the two-tone generator is replaced by a microphone, the peaks of the speech waveform must not be allowed to exceed the limits defined by the two lines on the oscilloscope (Fig 5). It is convenient to set up at this power level, as it leads directly to an indication on the oscilloscope of the maximum power permitted by the UK licence.

If the transmitter is not capable of operating at full power, a lower power can of course be used and the resulting deflection scaled up to represent

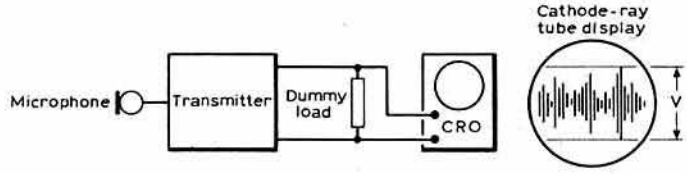

Fig 5. Peaks of speech shall not exceed level determined in two-tone test (Fig 4)

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400W p.e.p.. Alternatively the power corresponding to a particular deflection can be calculated. In scaling up or down, it must be remembered that the deflection of the oscilloscope beam is proportional to the voltage which caused it; but power is proportional to V^2, hence the power is proportional to the square of the deflection. For example, if the deflection corresponding to 400W p.e.p. is 5cm, and the deflection caused by speech peaks is 2.5cm, then the power corresponding to a deflection of 2·5cm is:

$$400 \times \frac{2 \cdot 5^2}{5^2} = 400 \times (\frac{2 \cdot 5^2}{5})^2 = 400 \times (\frac{1}{2})^2 = 100\text{W}$$

Questions and answers

A number of queries inevitably arise now, for example:

Q. A bit complicated, isn't it?

A. Yes! but it does get around the impossibility of determining the power input by trying to measure a rapidly varying current on a conventional meter.

Q. Why do I need a two-tone generator?

A. A single tone could be used. The ssb transmitter would then convert this to a single radio frequency (in effect, this would be a carrier wave). We would then have to set the output power to 400W and not 200W as in the two-tone case.

It is now that one has the paradoxical situation that when an ssb transmitter is transmitting a single tone, the p.e.p. output is equal to the rms (ie real) power output. In many ways, the term "maximum envelope power" would be preferable to "peak envelope power". It is essential, of course, to confirm that the transmitter is capable of operating at this level.

As a matter of interest, a three-(or more)-tone signal could be used, and the transmitter would then be set up to 400/3 or 133W (in the three-tone case). The two-tone source is generally used for reasons of simplicity. Any distortion of the transmitter output waveform when two-tone input is used is indicative of maladjustment or incorrect operation such as excessive drive, incorrect bias or loading on the pa or possibly excess carrier.

Q. Do I really have to do all this?

A. Most of the linear amplifiers available in the UK are capable of an output of more than 400W p.e.p.. Anyone using one of these may well be asked by a Post Office inspector to demonstrate that the licensed power is not being exceeded. Most transceivers have an output of 150W p.e.p. or less, so the question cannot arise. However, do not forget that one really should have a dummy load for tuning up, and also that the only effective way of checking the operation of an ssb transmitter is by an oscilloscope.

Q. Can I use a wattmeter to measure the power?

A. There appears to be no reason why a wattmeter of reputable make, incorporated in an antenna matching unit or used separately, should not be used. However, it may be difficult to persuade a Post Office inspector that a scruffy-looking home-made wattmeter has adequate accuracy.

Some wattmeters read p.e.p. direct by means of a long time-constant circuit to "add up" the peaks of the waveform over a period of several seconds. Thus a constant reading is obtained. Unless wattmeters are calibrated by the method discussed earlier, one has to assume that their accuracy is adequate. However, at the price now being charged for such meters, it is not unreasonable to expect documentary evidence of accuracy.

It should be noted that ssb transmitters and linear amplifiers are normally rated in terms of p.e.p. "input", eg a transceiver using two 6146 valves in the output stage is rated at an input of 200W p.e.p., and will give an output of 90–100W. These ratings are determined by the valve maker in his laboratory, the output corresponds to the efficiency to be expected from a Class AB stage.

Conclusion

It is hoped that the above will help the reader to understand the measurement of peak envelope power as required by the UK amateur licence. The theoretical background will be found in *Radio Communication Handbook*, 5th edn, pp 6.98–6.104.

This article started as a joint effort between the author and his old friend and ex-colleague, the late Alan Bayliss, G8PD/PA0AAR. It arose out of discussions and correspondence concerned with the preparation of the eighth edition of the *Radio Amateurs' Examination Manual.* □

Automatic transceiver break-in for a car

by LORIN KNIGHT, MIEE, G2DXK*

LIKE MANY OTHER READERS of *Rad Com*, the author has in his car both a normal broadcast-band receiver and a 144MHz transceiver. During a journey his interests may alternate between the two and, in order to simplify the change-over operation, he has built an automatic switching unit.

At the heart of this unit is a relay which switches the loudspeaker from the broadcast receiver to the transceiver. The relay remains unenergized so long as the transceiver is not in use, but is energized whenever the transceiver is switched to TRANSMIT or is receiving signals.

Basic operation

The circuit is shown in Fig 1. Any af output from the transceiver is fed via the transformer T1 to TR1, causing that transistor to conduct on peaks and charge-up the 22μF capacitor. This causes the Darlington pair, TR2 and TR3, to conduct and energize the relay RLA which switches the loudspeaker. When the transceiver is switched to TRANSMIT a second relay, RLB, is energized. This biases TR1 into conduction, producing the same result.

RLB has its coil in series with the 12V supply to the transceiver and is operated by the increased current which is drawn on TRANSMIT—in the author's case a change from around 150mA to around 2A. The relay was made by winding 40 turns of 36swg enamelled wire around a small reed switch, using a short length of plastic drinking straw for a bobbin. The relay operates with a current of about 1A. The 22μF capacitor provides a delay, holding RLA energized for one or two seconds after TR1 has ceased conducting.

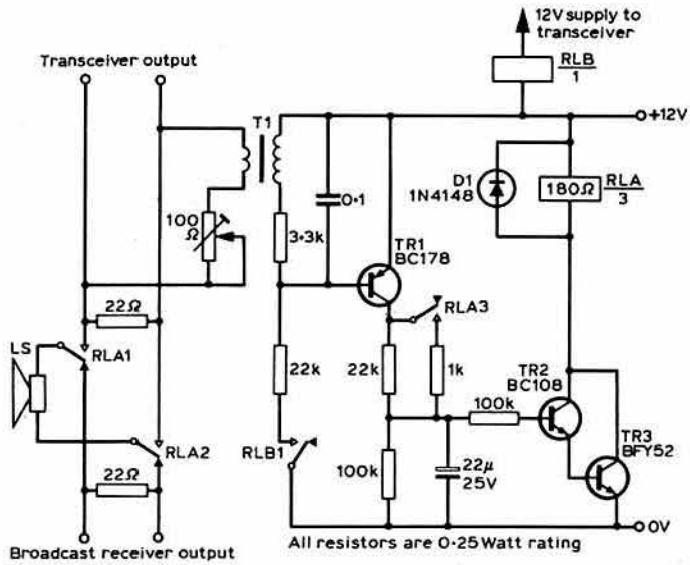

Fig 1. Circuit diagram of the switching unit

Tailoring the switching characteristics

Ideally one does not want the broadcast receiver to be muted by unwanted outputs from the transceiver such as:

(a) random clicks or bursts of interference;

(b) isolated syllables of speech from a weak signal which is only occasionally breaking the squelch; and

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